CHAPTER 1

SOIL NATURE AND FORMATION

ميكانيكا التربة .. تقديم

يتناول علم ميكانيكا التربة دراسة سلوك التربة فى أعمال الحفر وتحت تأثير المنشآت والطرق وكذلك تأثير المياه الجوفية .

ومنذ الثلاثينيات إهتمت الجامعة المصرية بهذا العلم , وبانتشار تطبيقاته كرس المهندس المدنى جزء من جهده لدراسة طبيعة التربة وميكانيكيتها بما ينعكس على سلامة التصميم لأساسات المبانى والكبارى وغيرها والطرق وميول الأتربة ومؤخرا الأنفاق .

والتربة المصرية فى وادى النيل وكذلك الترسيبات الصحراوية فى المدن الجديدة غنية بأنواعها المختلفة وصفاتها الهندسية المتنوعة مما يجعل فهم وتقييم سلوكها الهندسى تحديا ممتعا للمهندس المصمم ومهندس التنفيذ .

1.1 Introduction

The earth's crust (القشرة الارضية) is divided into rock and soil. Rock is a natural strongly cemented accumulation (تجمع) of particles of different minerals. Solid rock relatively has very high strength. Soil is the accumulation of solid particles produced by mechanical disintegration of rock and other weathering processes. It may contain organic constituents (مكونات عضوية) and water. There is no distinct division between rock and soil since fractured (متشقق) rock may be as strong as, or even weaker than, some types of soil.

Soil is the material which supports the foundation of all structures. It is also used as a construction material for earth dams, embankments and roads. In engineering practice, knowledge of the physical properties of soil and its behavior under load is very important. In recent years, study of the engineering aspects of soil gained great advances. The term Soil Mechanics has been introduced to account for the application of the laws of mechanics and hydraulics to engineering problems dealing with soil. The main objectives of Soil Mechanics is to present theories, principles and procedures by which the behaviour of soil in the field when exposed to structure loads can be understood and predicted.

1.2 History of development of soil mechanics

Soil Mechanics is considered a practical science, not a purely fundamental or mathematical one. In fact, advances in Soil Mechanics has resulted from development of empirical knowledge throughout all civilizations.

Since earliest times, mankind used to build with or on soil. The Ancient Egyptians built many types of buildings. They used to construct their important structures such as temples and pyramids on rock as a solid foundation. However, some structures reflect their knowledge, or sense, of some of the mechanical properties of soil. On 2000 B.C. They used timber and stone caissons (قيسونات) for construction in soft ground. The cutting edge (الخنزيرة) of the caisson was made of circular limestone block shaped as a ring. The outer surface of the caisson was made smooth such that side friction during sinking (التغويص) was reduced.

The Babylonians made an ancient remarkable construction which consisted of huge retaining walls supporting the famous hanging gardens (الحدائق المعلقة للبابليون). In Romans times numerous structures were built in a way which proved that they were aware (على دراية) of soil properties, even on empirical basis. Large public buildings, harbors, bridges, breakwaters, sewage lines, roads, etc. required solution of many soil mechanics and foundation problems.

During the following civilizations numerous heavy structures were built successfully and lasted for long decades. Some of them, however, suffered from excessive settlement (هبوط زائد) which occurred due to compressibility (انضغاط) of weak soil. The leaning Tower of Pisa, built 1173-1350 A.D. is a very famous example. Nevertheless, many foundation problems were handled successfully. An example is found in Taj Mahal in India where the terrace and the buildings adjacent to the river, as well as the minarets, were constructed on a compacted layer of masonry supported on masonry cylindrical wells sunk at close intervals. In Cairo, several old mosques with deep wells (sabil – سبيل) and remains of palaces indicate engineering knowledge of soil problems.

During the seventeenth and eighteenth centuries France made great advances in the field of public works and established the Department for Roads and Bridges in 1715. The first major scientific contribution in the field of Soil Mechanics came also from France when Coulomb (1776) published his wedge theory of earth pressure. He was the first to introduce the concept that the shear strength of soil consisted of two components, cohesion and friction

The next episode witnessed several scientific contributions. During 1788-1867 Poncelet gave the graphical solution of the earth pressure for vertical and inclined retaining walls. Culmann (1866) presented the graphical formulation of the earth pressure theory. In 1871 Rebhan presented also a graphical solution of the earth pressure problem. Darcy (1856) made his contribution of the flow of water through soil. In the same year Stoke presented the law for settlement of solid particle in a liquid. In 1857 Rankine published his earth pressure theory. He also suggested a method for calculating the bearing capacity (قدرة تحميل) of foundations. Boussinesq (1885) solved the problem of stress distribution in semi-infinite elastic medium under surface point load. In 1871 Mohr presented the graphical representation of stresses at a point.

The basic physical properties of soil were not understood until the beginning of the twentieth century. Atterberg (1911) was the first to propose the different stages of consistency (القوام) in which a clay soil mass exists depending on its water content. The shear strength of sand was first studied in the shear box perhaps by Leygue (1885), then this apparatus was improved by Terzaghi and Casagrande in U.S.A. and by Krey in Germany in 1918. More advances in the Rankine's earth pressure analysis were given by Resal (1910) and Bell (1915) which included both soil friction and cohesion in the analysis. Bell also developed a method for calculating the bearing capacity of cohesive soil. Petterson and Hultin (1916) used the circular sliding assumption to suggest the friction circle method of stability analysis. Fellenius, who was the chairman of the Swedish geotechnical commission, developed the Swedish circle method in 1926. In 1920 Prandtl presented the theory of plastic equilibrium. In 1922-23 Pavlovsky solved the complex problems of water seepage below hydraulic structures with the electrical analogy method.

In 1923 Terzaghi published his theory of one-dimensional consolidation, and in 1925 he published his book which was titled ***"Erdbaumechanik"***, the German equivalent of "**Soil Mechanics**". In the following years Terzaghi made numerous contributions in the field of Soil Mechanics and Foundations. He is considered the "Father of Soil Mechanics". An important development was made by Proctor (1933) on the principles of soil compaction (دمك التربة).

During the past 60 years great advances in soil mechanics and foundation engineering were made. Several institutions are established devotedly for geotechnical research. Since 1936 International Conferences are held each four years by the International Society for Geotechnical Engineering. Many other regional (اقليمى) and specialized conferences are held in which scientists and engineers present their contributions and exchange knowledge and experiences. Several periodical are published dealing solely with Soil Mechanics and Geotechnical Engineering.

In Egypt, Cairo University established the Foundations Research Laboratory in 1933. Great efforts were made by pioneers such as Dr. William Seleem Hanna, Dr. Mohamed Kamal Khalifa, Dr. Mohamed Said Youssef and many others in order to introduce Soil Mechanics trends to practicing engineers.

The soil properties in Cairo and in some other cities were investigated. Settlement studies of several public and private buildings were undertaken. These works were presented in the First International Conference and the following conferences. The first Egyptian to obtain Ph.D. degree (درجة الدكتوراه) in Soil Mechanics was Dr. Mohamed Kamal Khalifa. He wrote the first book published in Egypt on Soil Mechanics in 1946.

1.3 Formation of Soil (تكوين التربة)

يساعد فهم كيفية تكوين التربة فى إدراك كثير من خواصها . والتربة بصفة عامة هى تلك الحصوات والحبيبات المختلفة الحجم من المقاس الغروى (أقل من ٠,٠٠١ مم) الى الركام الناتجة من عمليات التجوية التى تتعرض لها للصخور.

وقد قسم الجيولوجيون التربة من ناحية التكوين الى تربة متبقية وهى ناتج تجوية الصخر فى نفس مكانه , وتربة منقولة تترسب فى مناطق بعيدة عن الصخور الأصلية الذى نتجت عنها , وهذه التربة تنقسم بدورها الى تربة مترسبة فى وبفعل المياه العذبة مثل تربة وادى النيل ومترسبة فى بفعل المياه المالحة مثل التربة فى شمال الدلتا وبورسعيد وتربة مترسبة بفعل الريح مثل الكثبان الرملية فى طريق القاهرة الاسماعيلية الصحراوى.

Soil is the product of the natural weathering of rocks. Soils have been continuously formed and then transported by rivers, wind and ice. They form through physical, chemical and organic weathering of rocks and the mechanical disintegration of rock fragments during transportation in streams, rivers, ice and wind.

1.3.1 Classification of soils with relation to their formation

Soils are classified according to their formation as follows:

(a) Residual soil : (تربة متبقية)

Residual soils are formed in-situ by weathering of the original rocks. They usually consist of stoney-clayey-sandy silts, Fig. 1.1.

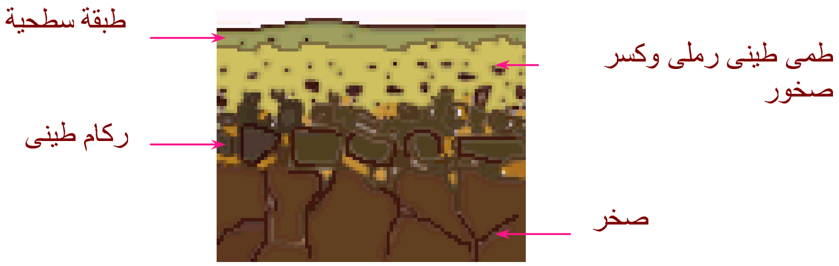


Fig. 1.1 Profile of residual soil

If the finer particles are leached out, they will be formed of residual rock debris (كسر الصخور). Rock fragments have sharp edges and include materials of the parent rock (الصخر الام).

(b) Transported soil : (تربة منقولة)

(i) **Alluvial deposits (ترسيبات المياه العذبة)** :
The water flowing down mountains, Fig.1.2, can carry rock fragments of varying sizes. Abrasion causes these fragments to become rounded forming boulders, cobbles, gravel and sand grains. The very fine products of this process form silt. Clay is formed by chemical alteration of some rock minerals.

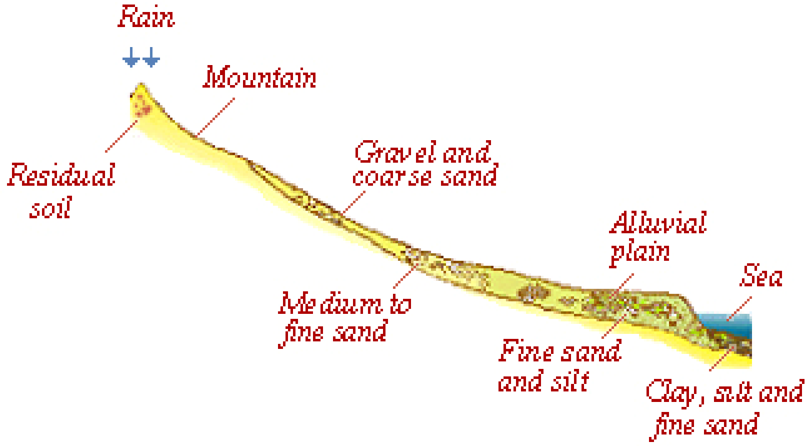


Fig. 1.2 Longitudinal section of a river and the type of alluvial sediments

It is generally found that the alluvial deposits become finer as the distance from their origin increases, and the distance from the bank in the direction perpendicular to stream increases. Lakes formed due to changes in stream course (مسار) are filled with fine sediments (called lacustrine deposits) formed mainly of organic silt and peat (مواد عضوية متحللة). Deltas also are formed of silt deposits interlayered with sand brought by seasonly (موسميا) flood.

(ii) **Marine deposits (ترسيبات المياه المالحة)** :

The particles of clay and silt are carried by rivers to the sea where they collect together and are laid down to form deposits of mud interlayered with fine sand brought during flood. Shallow water deposits include also beach sands (رمال شاطئية). Deep water deposits are formed of calcareous clay size particles, originally microscopic organisms, and brown clays.

(iii) **Wind below deposits (ترسيبات الرياح)** :

Wind blown deposits include sand dunes (كثبان رملية) which are formed of rounded, uniform and loose sand particles. The dunes may be mobile (متحرك), but when exposed to capillary rise of water they become stable. Loess (اللويس) is also a wind blown deposit formed mainly of silt with fine sand and clay. It is usually cemented immediately after its deposition by calcium compounds, iron oxides or other materials which gives it high dry strength. However, due to its open particle arrangement, loess collapses (ينهار) when exposed to foundation load then access (دخول) of water. Silt particles are picked up by strong winds and transported long distances then settled to form loose deposits. They are often cemented (e.g. with calcium carbonate) immediately after their deposition. Dry sands can also be moved by wind forming sand dunes. These sand dunes are continually movable until they reach moist ground becoming gradually immobile.

1.4 Soil formations in Egypt

The Nile Valley and Delta are formed of Nile alluvium. This alluvium is usually charaterized by upper layers of silt and clay followed by sand . In Cairo, the alluvium is normally topped by several meters of fill. Deposits near the Nile (e.g. El-Kornish, Shobra, Zamalek, Roda, Agouza) are mostly formed of silt and sand. Deposits far from the Nile (e.g. El-Qobba, Dokki, Al-Haram) usually contain layers of stiff clay. The thickness of Nile alluvium is about 20 to 25 m.

In the Delta, erratic (غير منتظم) formations are encountered. Layers of organic soil (or peat) exist in several locations particularly from Mansoura to Domiat. The northern parts of the Delta are affected by the marine environment (بيئة). They have different formation characterized by "soft" clay layers.

The formations bordering the Nile in the south are Nobian Sandstone (طبقات حجر رملى وطين) and igneous rocks. Cretaceous Formations (الحجر الجيرى والحجر الطينى الصفائحى) outcrop opposite to Kom Ombo and extend to Nag Hammadi. The northern areas up to Cairo are Eocene formations (تتابعات من الحجر الرملى الجيرى والحجر الجيرى والمرل والطين). In the area between the alluvial plain and the cliffs, also in the small valleys draining into it, there exist normally minor deposits of Pliocene and Pleistocene deposits (حجر رملى جيرى ورمل مع قواقع وطين).

From Cairo northwards the Eocene Formation is followed by Oligocene Formation consisting of gravels, sands and sandstones, and a sheet of dolerite (basalt), followed by Miocene Formation of sandstones, limestones and clays. West of the Delta Pliocene Formation of sands and gypseous clays overly the Miocene formation. Pleistocene and Recent deposits consisting of gravel and sand border the remaining part of the Delta on both sides as far as the Mediterranean sea.

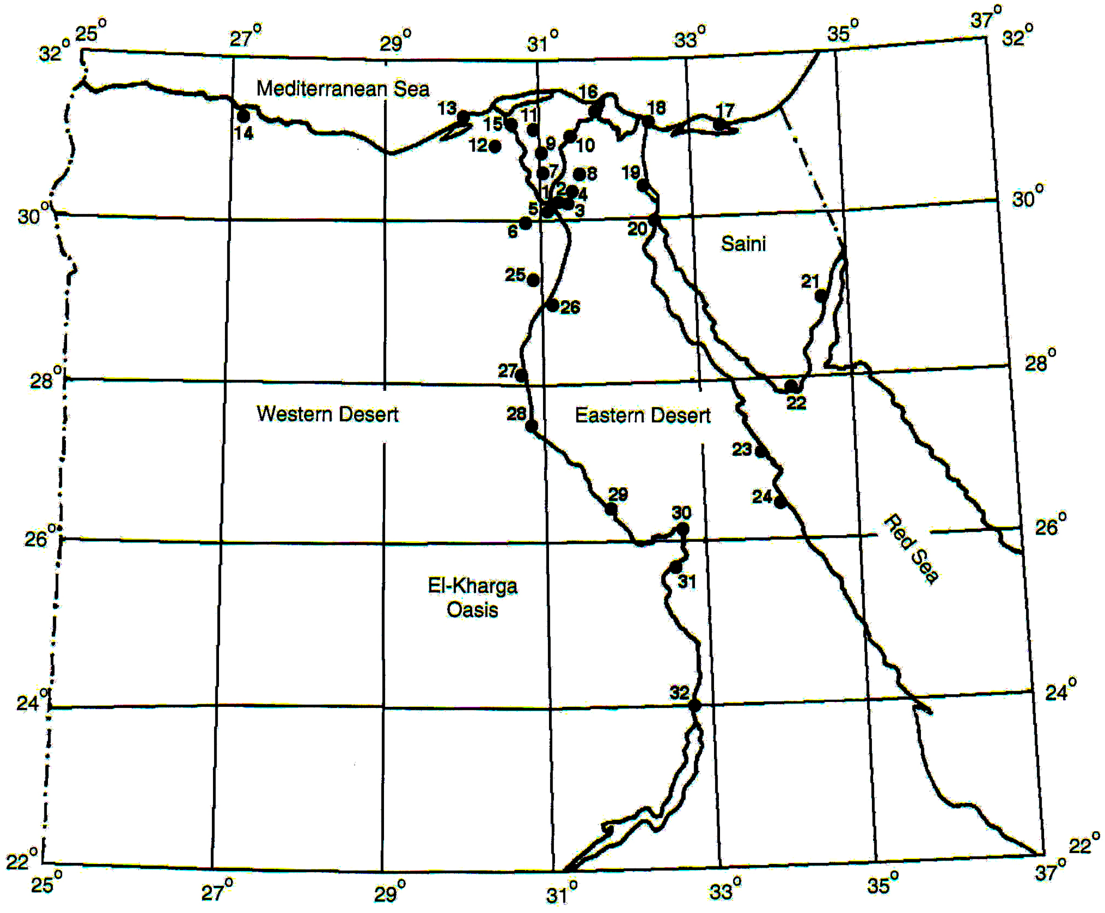
It should be mentioned that the clays in the Desert formations are usually of the expansive (قابل للانتفاش) nature which undergoes marked volume change when exposed to change in water content. Problems associated with expansive clays, called "bagah" (باجه) have been encountered in Aswan, Esna, El-Kharga Oasis, El-Dakhla Oasis, New Maadi, Madinet

Nasr, Sixth of October City, Tenth of Ramadan City, Suiz, Hurgada, and many other locations.

Typical borehole logs (قطاعات جسات) in several locations in Egypt, Fig. 1.3, are shown in Fig. 1.4. These logs show possible succession of soil layers (تتابع طبقات التربة) within the locality.

These logs represent the soil formation at the specific site where they are executed and NOT the formation of the whole region.

Fig. 1.7 shows examples of soil *borehole logs* at some locations in both Nile deposits and "desert" deposits.



اماكن الجسات :

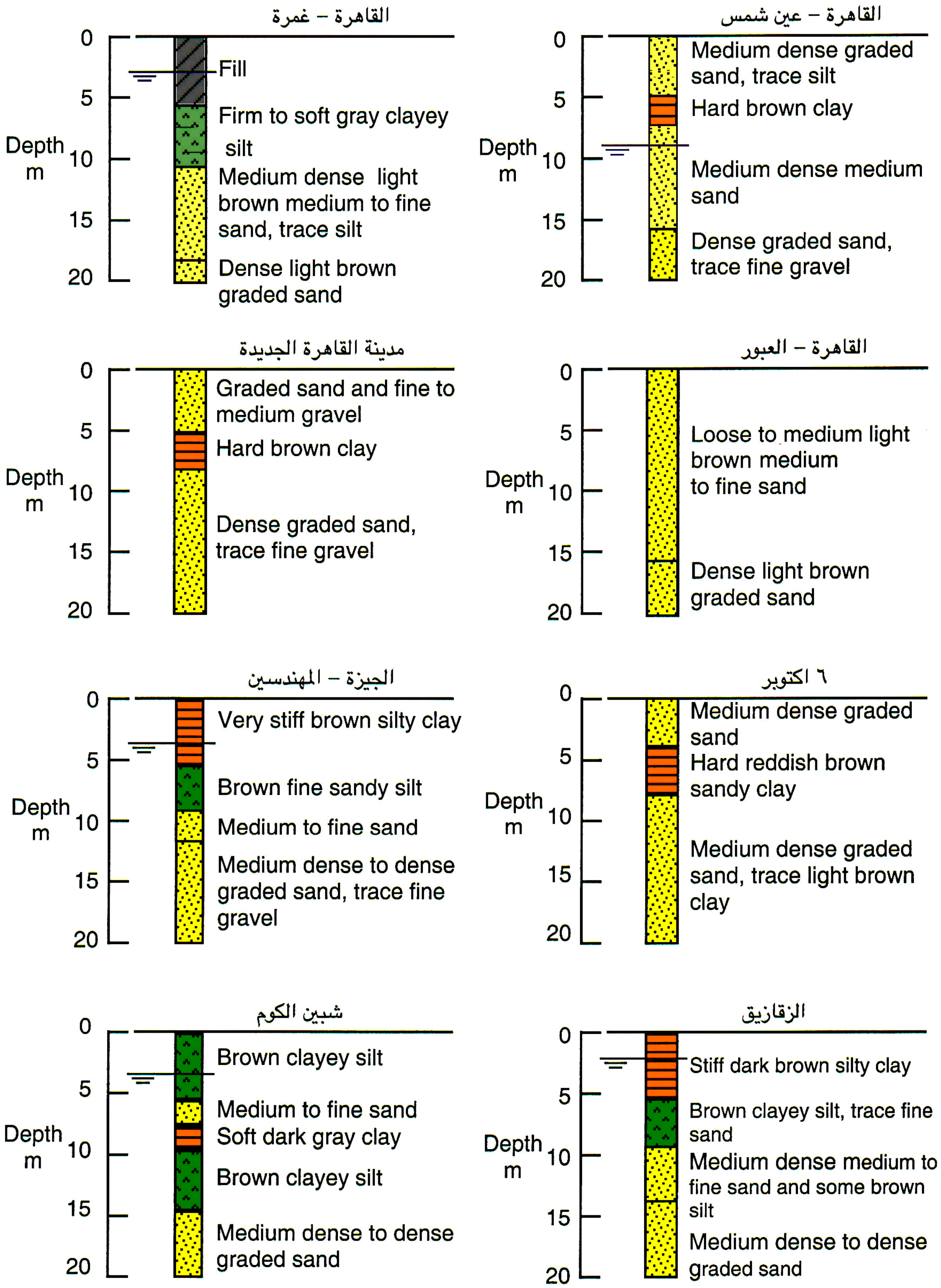
(١) القاهرة – غمره
(٢) القاهرة – عين شمس
(٣) مدينة القاهرة الجديدة
(٤) مدينة العبور
(٥) الجيزة – المهندسين
(٦) مدينة ٦ اكتوبر
(٧) شبين الكوم
(٨) الزقازيق

(٩) طنطا
(١٠) المنصورة
(١١) كفر الشيخ
(١٢) دمنهور
(١٣) الاسكندرية
(١٤) مرسى مطروح
(١٥) فوه – كفر الشيخ
(١٦) دمياط

(١٧) العريش
(١٨) بورسعيد
(١٩) الاسماعيلية
(٢٠) السويس
(٢١) نويبع
(٢٢) شرم الشيخ
(٢٣) الغردقة
(٢٤) راس غارب

(٢٥) الفيوم
(٢٦) بنى سويف
(٢٧) المنيا
(٢٨) اسيوط
(٢٩) سوهاج
(٣٠) قنا
(٣١) الاقصر
(٣٢) اسوان

Fig. 1.3 Map of Egypt


القاهرة – غمرة
Depth m
0
5
10
15
20
Fill
Firm to soft gray clayey silt
Medium dense light brown medium to fine sand, trace silt
Dense light brown graded sand
القاهرة – عين شمس
Depth m
0
5
10
15
20
Medium dense graded sand, trace silt
Hard brown clay
Medium dense medium sand
Dense graded sand, trace fine gravel
مدينة القاهرة الجديدة
Depth m
0
5
10
15
20
Graded sand and fine to medium gravel
Hard brown clay
Dense graded sand, trace fine gravel
القاهرة – العبور
Depth m
0
5
10
15
20
Loose to medium light brown medium to fine sand
Dense light brown graded sand
الجيزة – المهندسين
Depth m
0
5
10
15
20
Very stiff brown silty clay
Brown fine sandy silt
Medium to fine sand
Medium dense to dense graded sand, trace fine gravel
٦ اكتوبر
Depth m
0
5
10
15
20
Medium dense graded sand
Hard reddish brown sandy clay
Medium dense graded sand, trace light brown clay
شبين الكوم
Depth m
0
5
10
15
20
Brown clayey silt
Medium to fine sand
Soft dark gray clay
Brown clayey silt
Medium dense to dense graded sand
الزقازيق
Depth m
0
5
10
15
20
Stiff dark brown silty clay
Brown clayey silt, trace fine sand
Medium dense medium to fine sand and some brown silt
Medium dense to dense graded sand

1 of 4

Fig. 1.4 Typical borehole logs in some locations in Egypt (cont.)

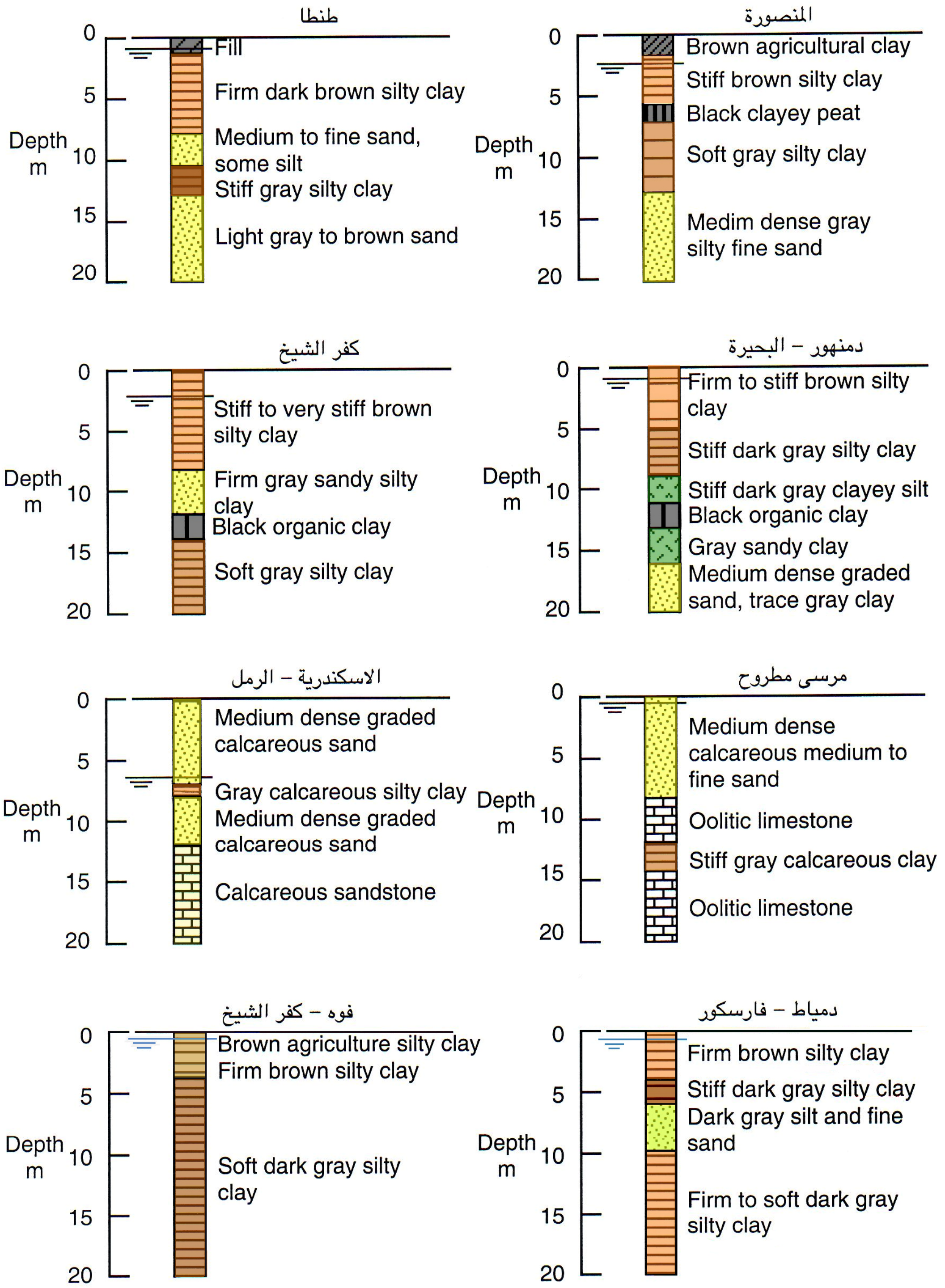

طنطا
Depth m
0
5
10
15
20
Fill
Firm dark brown silty clay
Medium to fine sand, some silt
Stiff gray silty clay
Light gray to brown sand
المنصورة
Depth m
0
5
10
15
20
Brown agricultural clay
Stiff brown silty clay
Black clayey peat
Soft gray silty clay
Medim dense gray silty fine sand
كفر الشيخ
Depth m
0
5
10
15
20
Stiff to very stiff brown silty clay
Firm gray sandy silty clay
Black organic clay
Soft gray silty clay
دمنهور – البحيرة
Depth m
0
5
10
15
20
Firm to stiff brown silty clay
Stiff dark gray silty clay
Stiff dark gray clayey silt
Black organic clay
Gray sandy clay
Medium dense graded sand, trace gray clay
الاسكندرية – الرمل
Depth m
0
5
10
15
20
Medium dense graded calcareous sand
Gray calcareous silty clay
Medium dense graded calcareous sand
Calcareous sandstone
مرسى مطروح
Depth m
0
5
10
15
20
Medium dense calcareous medium to fine sand
Oolitic limestone
Stiff gray calcareous clay
Oolitic limestone
فوه – كفر الشيخ
Depth m
0
5
10
15
20
Brown agriculture silty clay
Firm brown silty clay
Soft dark gray silty clay
دمياط – فارسكور
Depth m
0
5
10
15
20
Firm brown silty clay
Stiff dark gray silty clay
Dark gray silt and fine sand
Firm to soft dark gray silty clay

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Fig. 1.4 Typical borehole logs in some locations in Egypt (cont.)

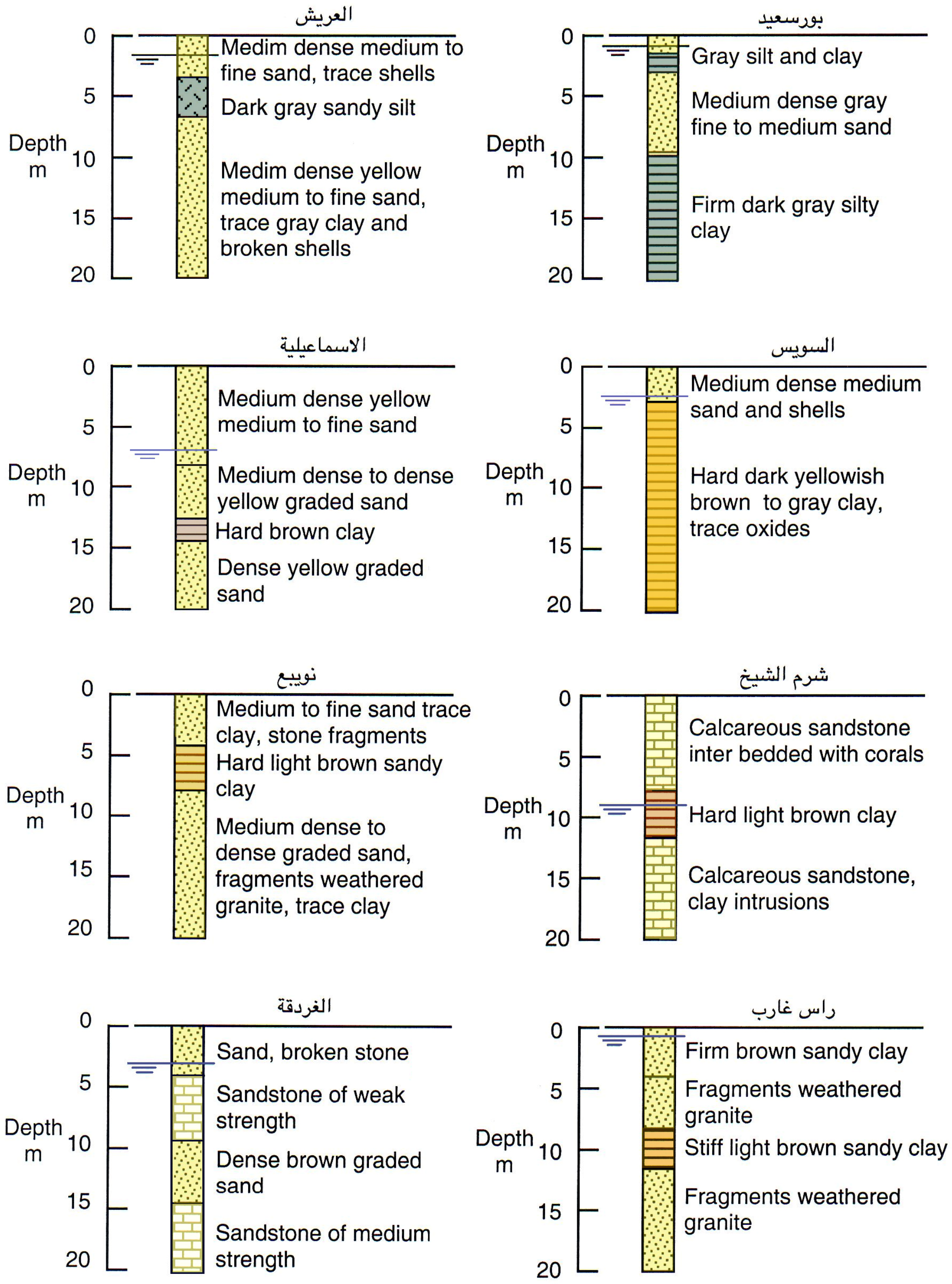
العريش
Depth m
0
5
10
15
20
Medim dense medium to fine sand, trace shells
Dark gray sandy silt
Medim dense yellow medium to fine sand, trace gray clay and broken shells
بورسعيد
Depth m
0
5
10
15
20
Gray silt and clay
Medium dense gray fine to medium sand
Firm dark gray silty clay
الاسماعيلية
Depth m
0
5
10
15
20
Medium dense yellow medium to fine sand
Medium dense to dense yellow graded sand
Hard brown clay
Dense yellow graded sand
السويس
Depth m
0
5
10
15
20
Medium dense medium sand and shells
Hard dark yellowish brown to gray clay, trace oxides
نويبع
Depth m
0
5
10
15
20
Medium to fine sand trace clay, stone fragments
Hard light brown sandy clay
Medium dense to dense graded sand, fragments weathered granite, trace clay
شرم الشيخ
Depth m
0
5
10
15
20
Calcareous sandstone inter bedded with corals
Hard light brown clay
Calcareous sandstone, clay intrusions
الغردقة
Depth m
0
5
10
15
20
Sand, broken stone
Sandstone of weak strength
Dense brown graded sand
Sandstone of medium strength
راس غارب
Depth m
0
5
10
15
20
Firm brown sandy clay
Fragments weathered granite
Stiff light brown sandy clay
Fragments weathered granite

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Fig. 1.4 Typical borehole logs in some locations in Egypt (cont.)

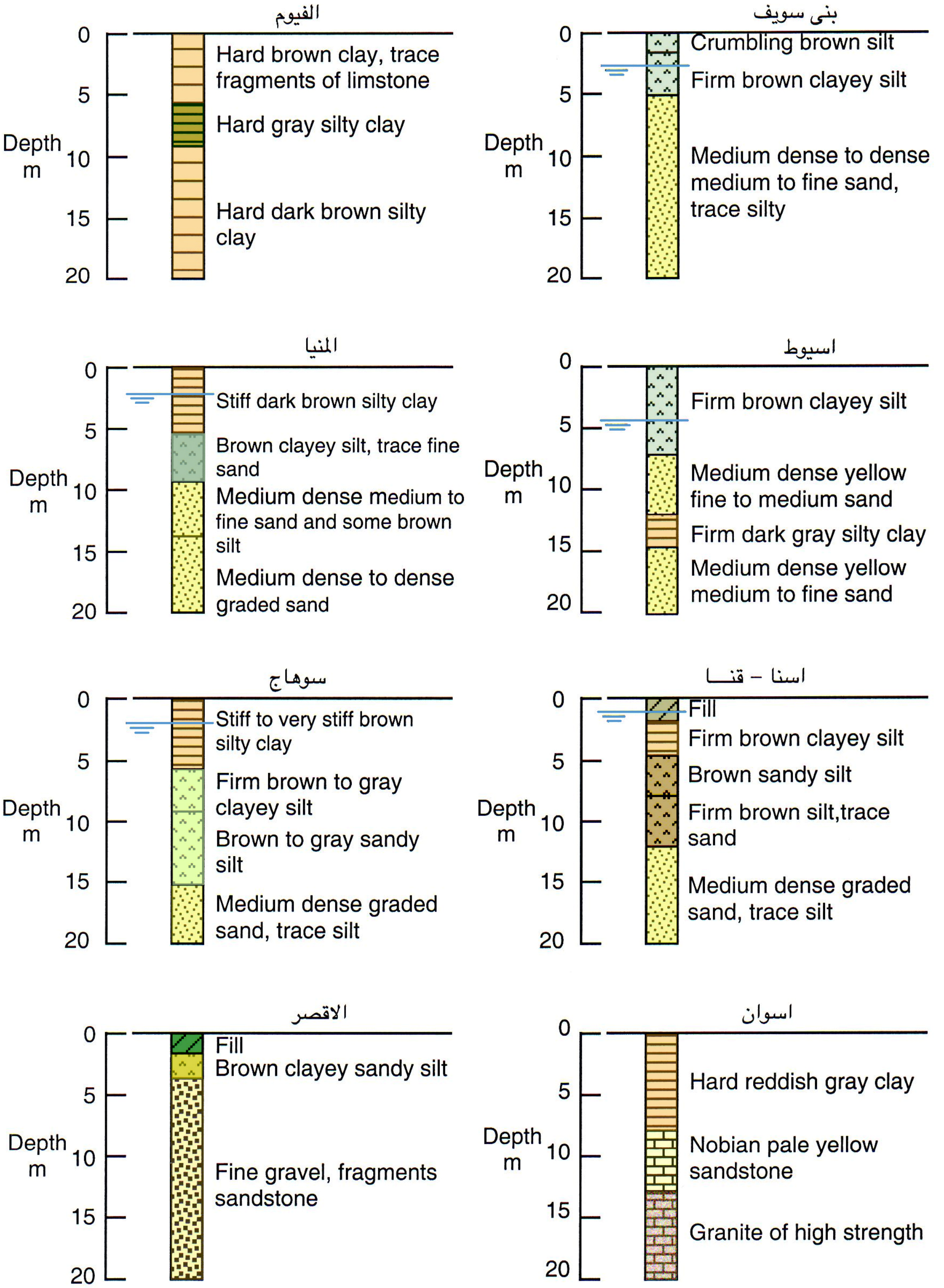
الفيوم
Depth m
0
5
10
15
20
Hard brown clay, trace fragments of limstone
Hard gray silty clay
Hard dark brown silty clay
بنى سويف
Depth m
0
5
10
15
20
Crumbling brown silt
Firm brown clayey silt
Medium dense to dense medium to fine sand, trace silty
المنيا
Depth m
0
5
10
15
20
Stiff dark brown silty clay
Brown clayey silt, trace fine sand
Medium dense medium to fine sand and some brown silt
Medium dense to dense graded sand
اسيوط
Depth m
0
5
10
15
20
Firm brown clayey silt
Medium dense yellow fine to medium sand
Firm dark gray silty clay
Medium dense yellow medium to fine sand
سوهاج
Depth m
0
5
10
15
20
Stiff to very stiff brown silty clay
Firm brown to gray clayey silt
Brown to gray sandy silt
Medium dense graded sand, trace silt
اسنا - قنـا
Depth m
0
5
10
15
20
Fill
Firm brown clayey silt
Brown sandy silt
Firm brown silt,trace sand
Medium dense graded sand, trace silt
الاقصر
Depth m
0
5
10
15
20
Fill
Brown clayey sandy silt
Fine gravel, fragments sandstone
اسوان
Depth m
0
5
10
15
20
Hard reddish gray clay
Nobian pale yellow sandstone
Granite of high strength

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Fig. 1.4 Typical borehole logs in some locations in Egypt

1.5 Soil Structure (تركيب التربة)

The arrangement of soil particles is called soil structure. It depends on the type of soil and its mode of deposition.

1.3.1 Particle arrangement in coarse grained soil (ترتيب الحبيبات الكبيرة للتربة):

تتميز التربة الخشنة بأن حبيباتها ترتكز بعضها على بعض ، ويختلف تركيبها حسب تدرج التربة (أى تنوع مقاس حبيباتها) وشكل الحبيبات وظروف الترسيب. فى التربة الكثيفة تتداخل الحبيبات الصغيرة والكبيرة وتكثر نقط الاتصال بينهما , بينما فى التربة المفككة تقل نقط الإتصال بين الحبيبات ليبدو التركيب محتويا على فراغات كبيرة تتزن بفعل الـ (Arching action) .

The structure of a coarse grained soil is governed by gravitational forces. Under the influence of gravity the coarse grains form a particle contact. Fig 1.٥ shows that coarse particles can may be packed in different structures ranging from dense to loose.

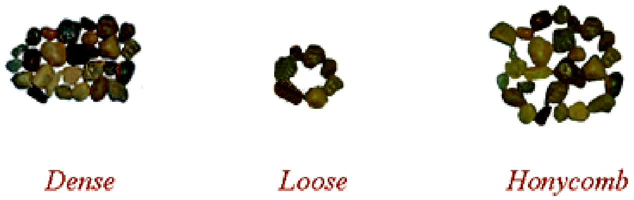
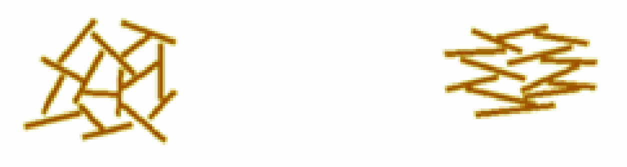


Fig. 1.5 Types of single grained structure

1.3.2 Particle arrangement in fine grained soil :

يلاحظ أن تكوين التربة الطينية المترسبة فى المياه الملحة مفتوح لتقابل أحرف بعض الحبيبات مع أسطح الحبيبات الاخرى مما يجعل التربة أقل قوة وتماسكا من التربة المترسبة فى المياه العذبة التى تتقابل أسطحها.

The structure of fine grained soils (diameter < 0.002 mm) is governed by the electrical forces acting at the surfaces of the particles. The influence of gravity is insignificant in this case. Such material, in which the influence of surface electrical changes is predominant, is said to be in **colloidal state** (حالة غروية). Colloids are conventionally of effective diameter < 0.001 mm. If the net electrical forces between adjacent soil particles in the time of deposition are attraction, a flocculated structure is formed; if the net electrical forces are repulsion, a dispersed structure is formed, Fig 1.6.



Flocculated
(ترسيبات مياه مالحة)

Dispersed
(ترسيبات مياه عذبة)

Fig. 1.6 Fundamental types of clay structure

The clay structure in nature is very complex (معقد) and is mostly affected by the amount and type of clay mineral present, the proportion of silt and sand content, depositional environment (بيئة الترسيب) and chemical nature of the pore water. A wide variety of common structural forms are shown in Fig. 1.7.

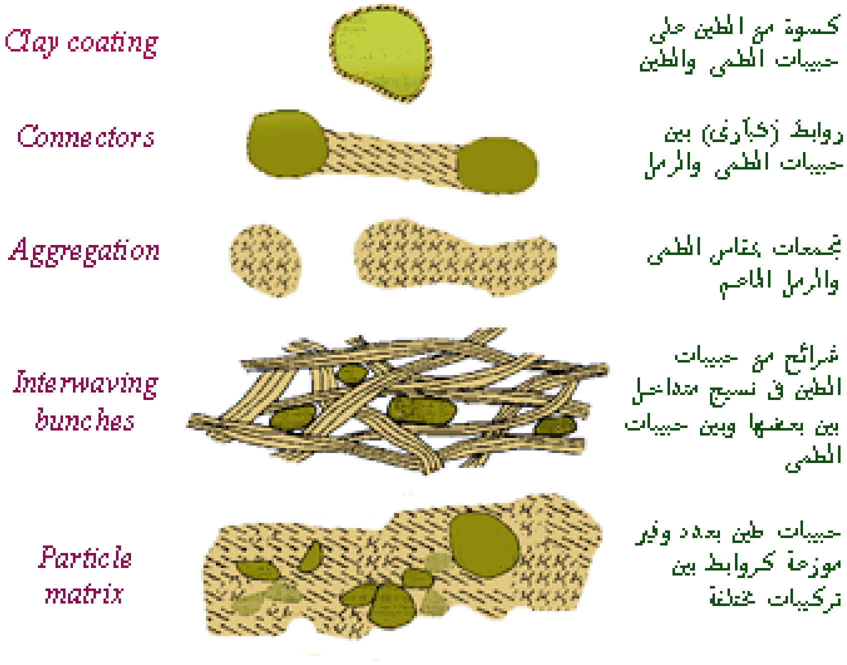


Fig. 1.7 Clay particle arrangement

Fig. 1.8 illustrates a micrograph of an expansive clay (طين قابل للإنتفاش) showing the clay structure as obtained by the scanning electron microscope (الميكروسكوب الألكترونى الماسح).

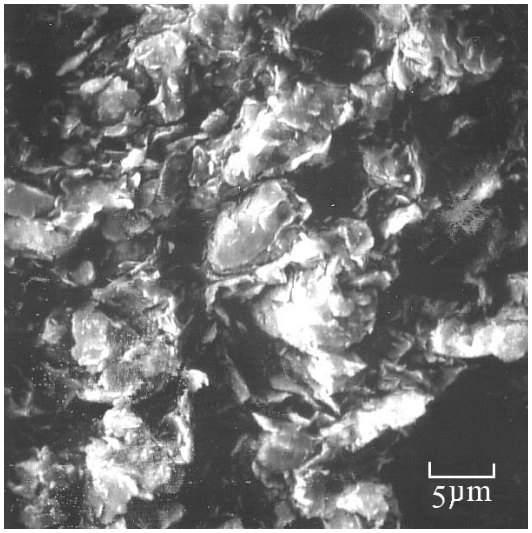


Fig. 1.8 Micrograph of expansive clay from El-Gharga

The macro-structure of a clay soil comprises the structure which can be seen with the naked eye (العين المجردة) and generally consists of features produced during deposition such as inclusions (تداخلات), partings (انقسامات), laminations (رقائق), varves (اسطح الترسيب الموسمية) and features produced after deposition such as as fissures (تشققات), joints (فواصل), shrinkage cracks (كسور انكماش), root holes (حفر جذور).

Fig. 1.9 shows the macro-structure of a very stiff aluuvial (Nile) clay. The varves are clearly shown, also the shrinkage cracks and fissures.

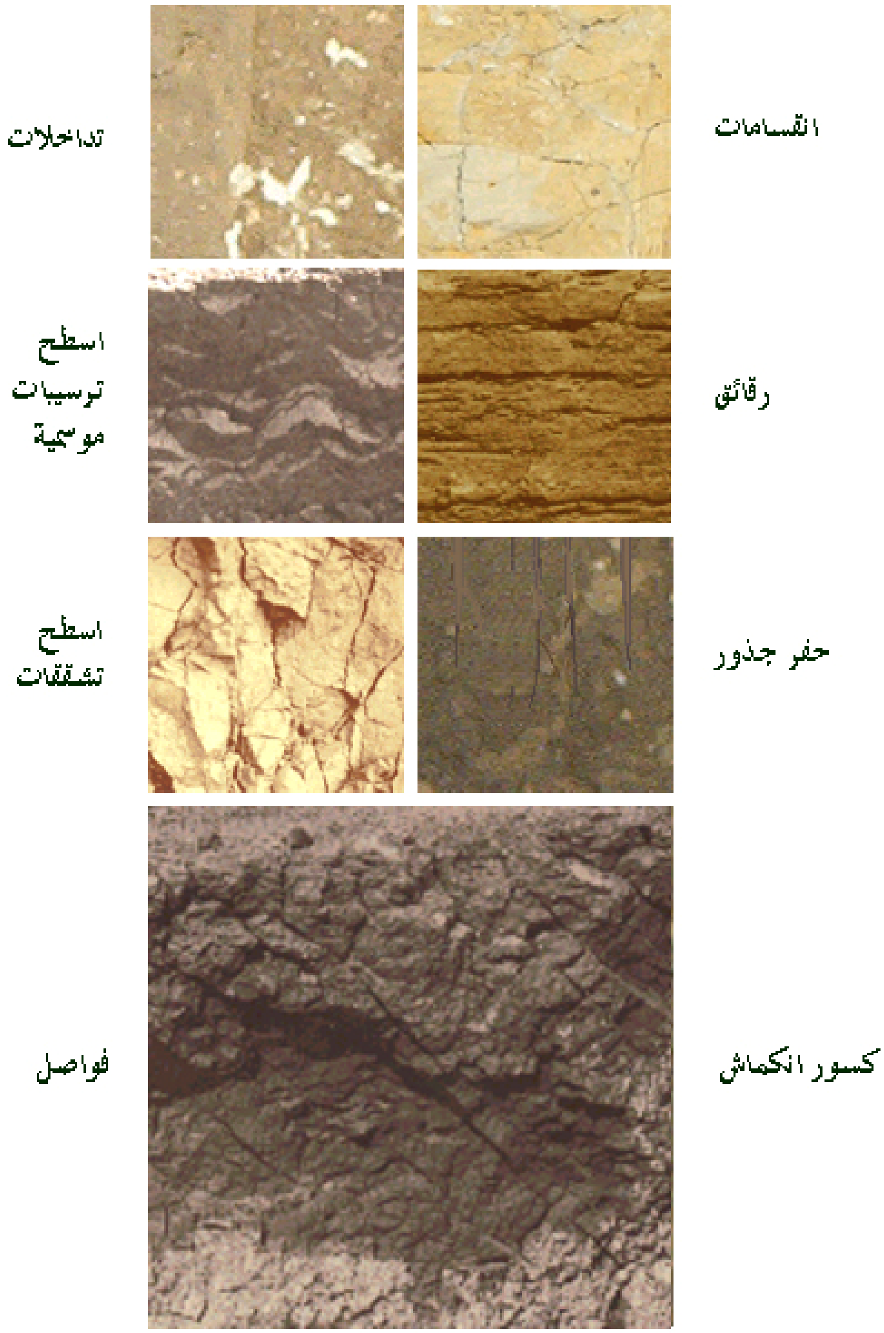


Fig. 1.9 Macro-structure features of clay deposits

1.6 Clay mineralogy

توجد أنماط عديدة من التركيبات البلورية لمعدن الطين . ويمكن الكشف عن هذه التركيبات ومعرفة مكوناتها بواسطة التحليل بأشعة إكس والتحليل الحراري النسبى وتحليل إمتصاص الصبغة والتحليل الكيميائى والتحليل بالميكروسكوب الإليكتروني.

وتعتبر وحدتى السيليكا الرباعية , والألومينوم (أو الحديد أو المغنسيوم) الثمانية , المكون الرئيسى لبلورة الطين . وتختلف نظم إتصال هذه الوحدات , كما تختلف أنواع المعادن المتداخلة معها , بدرجة كبيرة مما ينتج عن ذلك عديد من الأنواع من الطين. وبلورة الطين بصفة عامة قشرية لها سمك رقيق جدا جدا بالمقارنة بمسطحها , والشحنة الكهربية على سطحها غير متعادلة مما يجذب اليها بقوة أيونات الماء.

ويهتم المهندس ببعض "المجموعات" من المعادن الطين , بعضها مجموعة معدن **الكاولينايت** ومجموعة معدن الطين **الاليت** وهما من مجموعات الطين الثابتة التركيب , ثم مجموعة معدن **المنتموريلونايت** (يعرف تجاريا بالبنتونايت) التى تعطى أنواعا من الطين عند تعرضه للمياه وهو جاف أو غير مشبع يمتص المياه بشراهة وتدخل أيونات المياه فى نسيج الطين البلورى مما يسبب إنتفاش حبيبات الطين الصلبة نفسها وينتج عن ذلك إنتفاش التربة بقوة مما يعرض المبانى المقاومة عليها لإجهادات زائدة قد تسبب تصدعها. وهذا النوع من الطين موجود فى أسوان ويطلق عليه محليا "باجة" وموجود أيضا فى مدينة نصر والمعادى الجديدة ومدينة العاشر من رمضان ومدينة الشروق وكثير من المناطق الصحراوية فى مصر. والتربة النيلية تتضمن طبقات طينية تحتوى بعضها أيضا على نسبة صغيرة من معدن المنتموربلونايت من يجعلها قابلة للانكماش الشديد اذا انخفضت المياه الجوفية عنها وجفت ، ثم للإنتفاش إذا تسربت اليها المياه.

Clays are formed of very small particles of hydrous alumina silicates, shaped as extremely thin sheets. They behave as plastic material when mixed with small amount of water. They are highly resistant to weathering agents.

There are two fundamental building blocks for a clay mineral structure:

(a) Silica tetrahedral unit

The silica tetrahedral unit, Fig. 1.10, has four faces. It consists of four oxygens or hydroxyls enclosing a silicon atom. The chemical formula of the tetrahedral is $(Si_4O_{10})^{4-}$. Its symbolic shape is as shown. The tetrahedral are combined with the neighboring units forming hexagons.

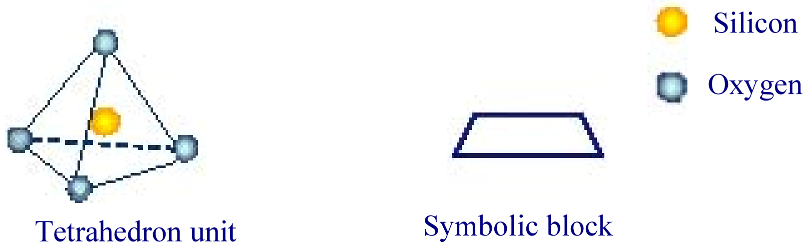


Fig. 1.10 The silica tetrahedra

(b) Octahedral unit "Gibbsite"

The octahedral unit has eight faces, Fig. 1.11. It consists of an aluminum, iron or magnesium atom enclosed in six hydroxyls. Its symbolic block is as shown. If the enclosed atom is aluminum, the octahedral unit is called "gibbsite" with chemical formula $Al_2(OH)_6$. If the enclosed atom is magnesium, it is called "brucite" with chemical formula $Mg_3(OH)_6$. The octahedral are arranged in sheets bounded from the top and bottom by two planes of (OH).

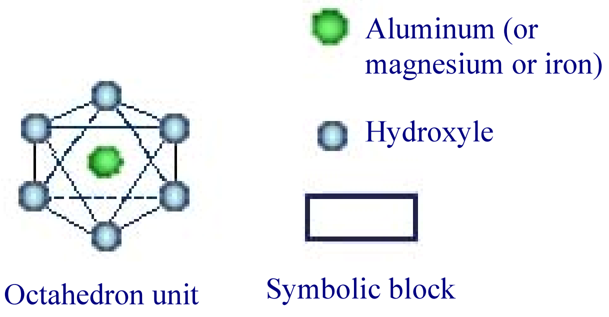


Fig. 1.11 The octahedra

Clay minerals are formed from silica tetrahedral and octahedra in numerous arrangements. A number of the silicon atoms in the tetrahedral may be substituted by aluminum atoms, and a number of the aluminum atoms in the octahedral may be substituted by magnesium or iron atoms. This is called "isomorphous substitution".

Three main clay mineral groups are well known. These are, Fig 1.12 :

(a) Kaolinite:

It is formed of gibbsite sheets joined to silica sheets. The structure of kaolinite is like that of a book, each leaf is $7x10^{-7}$ mm thick having the shown form. Successive sheets are held together by hydrogen bonds. The kaolinite particle is

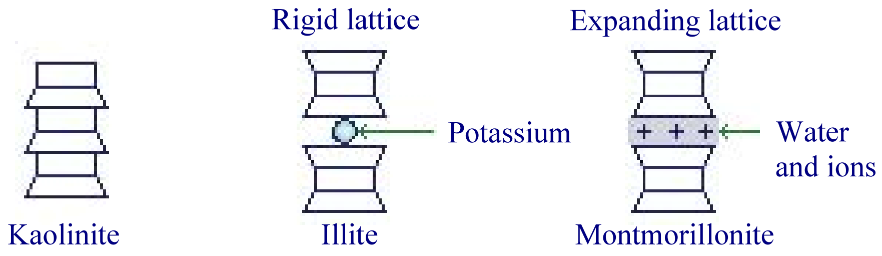


Fig. 1.12 Structure of famous clay minerals

a plate, 10^{-2} to $2x10^{-3}$ mm wide, and 10^{-5} to 10^{-4} mm thick. Since hydrogen bond is fairly strong, it is extremely difficult to separate the layers, and as a result kaolinite is relatively stable and water is unable to penetrate between the layers.

(b) Illite :

It is formed of successive units each of a gibbsite sheet sandwitched between two silica sheets. There is partial replacement of the silicon by aluminum in the silica sheets which is balanced by potassium between the layers. The bond of illite is weaker than the hydrogen bond, and the illite crystal has greater tendency (قابلية) to split (تتشطر) than that in kaolinite. Illite structure does not allow water movement between the sheets. Illite clay particle may be 10^{-} to $5x10^{-}$ mm in lateral dimensions, and $5x10^{-}$ to $5x10^{-}$ mm thick.

(c) Montmorillonite :

It is similar to illite, besides gibbsite layer may include atoms of aluminum,_iron, magnesium, or a combination of these. The silicon atoms of tetrahedra may interchange with aluminum atoms. Cations in soil water (e.g. Na+, Ca++, K+ etc) are attracted to the surfaces of clay plates and exist in a state of continuous state of interchange. Successive sheets are very weakly bonded and water may enter between the sheets causing montmorillonite to swell. The thickness of montmorillonite unit, or sheet, is 10^{-} mm; lateral dimensions are indefinite.

1.7 Nature of clay water system

تظهر الخاصية الصلصالية فى الطين بسبب "إندماج" جزيئات المياه المتاخمة للأسطح البلورية الخارجية لحبيباته مع التركيب المعدنى لتلك الأسطح . وتتسم خاصية الاندماج بتجاذب قوى يقل تدريجيا مع البعد عن سطح الحبيبة. وتعتمد قوى التجاذب وبالتالى قابلية الطين للعجن (اللدونة) على نوع الطين والخواص الكيميائية للاملاح الذائبة فى المياه . وتكوين المياه المندمجة يتصف باللزوجة العالية لاختلاف تركيبه عن الماء العادى مما يجعل خواصه الطبيعية مختلفة عن خواص الماء العادى (الماء الحر) وتنتج عنه خاصية الالتصاق التى يتصف بها الطين .

When clay is mixed with water a plastic material can be formed. Different clays may be distinguished by their plasticity characteristics because these characteristics vary with the surface activity of the constituent particles.

The phenomenon of plasticity of clay–water system may be explained by examining the nature of water near the surface of clay particle, Fig. 1.13. Since water is dipolar (ثنائية القطب) in molecular structure, the water in the vicinity (بالقرب) of clay particle is effectively immobilized (غير قابل للحركة) by the surface charge. It is **adsorbed** (مندمجة) and may be considered essentially solid. As distance from the particle surface increases, the orientation (اتجاه) of water is reduced in degree until, at the boundary of the particle‘s influence (limit of diffuse double layer), the viscosity is that of free water.

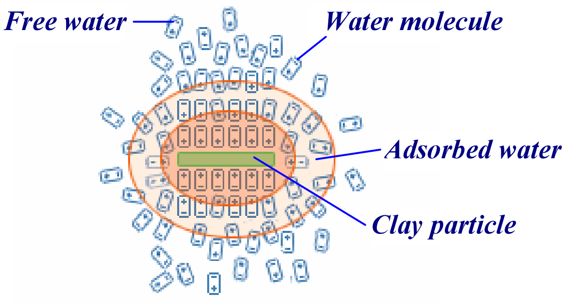


Fig. 1.13 The clay water system

With an abundance of water, soil would be separated by free water and the mixture would be fluid. As the amount of water decreases, the particles are separated by increasingly stiffer water. The mixture become as a solid. The soil water system, thus, has a range of water content over which it may be plastic. Change the constituent phases (soil type, or fluid) causes a change in the plasticity range. This permits us to distinguish among soils on the basis of their plasticity.

1.8 Questions

Answer Yes or No:

(1) Application of the rules of soil mechanics is required when studying the following subjects:

(i) Construction of buildings. (Y / N)
(ii) Construction of roads. (Y / N)
(iii) Petroleum industry. (Y / N)
(iv) Land reclamation (Y / N)
(v) Disposal of nuclear waste. (Y / N)

(2) Natural soils have the following properties :

(i) Particles of residual soils get finer with depth. (Y / N)
(ii) Stone fragments in the top layers of residual soils have exactly the same mineralogical composition as that of the bottom layers. (Y / N)
(iii) A soil consisting of successive layers of sand–silt and rock debris can be considered as a residual soil. (Y / N)
(iv) Alluvial deposits at the river bank are generally coarser than deposited far from the river. (Y / N)
(v) Marine clayey deposits are generally denser than alluvial clayey deposits. (Y / N)
(vi) Soil forming sand dunes is formed of particles of nearly equal size. (Y / N)

(3) Soil structure has the following characteristics :

(i) Sand gravel mix is always stable. (Y / N)
(ii) Sand deposited in water is more stable than that deposited in a dry condition. (Y / N)
(iii) Clay mixed with sand is always flocculated

(4) Clay mineralogy indicates that :

(i) Kaolinite crystals are formed only from silicon and aluminum. (Y / N)

(ii) Illite is more stable than montmorillonite. (Y / N)

(iii) Natural clays having abundant fraction of montmorillonite can be troublesome (Y / N)

(iv) Equal quantities of clay take also equal quantities of water to become plastic paste. (Y / N)

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